The organizational effect of prenatal testosterone upon gender role identity and mental toughness in female athletes

Abstract

Research has identified a correlation between prenatal markers of testosterone (2D4D) and sport performance. This relationship is thought to be explained by several important psychophysiological variables such as physical fitness and mental toughness. The current study sought to add to this body of research by examining the differences between high and low 2D4D, in measures of gender identity (BSRI) and mental toughness (MTQ48). A sample of 116 recreational (n= 59) and competitive netballers (n= 57) completed the psychological measures and provided right-hand scans from which 2D4D ratio measures were drawn. The key results included a large effect of low digit ratio on emotional control, life control and interpersonal confidence. These findings suggest that 2D4D could provide a marker for sporting potential and mental toughness in female sport participants. However, future research may wish to establish the relative contribution of prenatal factors (such as 2D4D) and socialization factors (involvement in a sporting context) on sporting ability and related psychological variables.

The organizational effect of prenatal testosterone upon gender role identity and mental toughness in female athletes

There have been research developments around individual differences in biological markers of hormonal development. There are several sources of evidence to suggest that the 2D4D ratio is an indicator of fetal sex hormones such as testosterone and oestrogen. The 2D4D ratio is a putative marker of prenatal testosterone exposure that has been utilized as an important non-invasive biomarker in research. First, these sex differences in 2D4D are already observable at the end of the first trimester of fetal development and individual differences appear to emerge prenatally (Malas, Dogan, Evcil & Desdicioglu, 2006) which are fairly stable during postnatal growth (Trivers, Manning & Jacobson, 2006). Second, the second digit growth is stimulated by oestrogen and the fourth digit by testosterone (Manning, 2002) and sex differences in 2D4D are unaffected by puberty (Manning, Scutt, Wilson & Lewis-Jones, 1998). Researchers have suggested possible causal factors for these differences including; sex steroids could influence relative bone lengths by facilitating the development of phalangeal anlagen during the perinatal period or metaphyseal growth. Alternatively, sex differences in digit ratios could arise if bones from different fingers are differentially receptive to sex steroids or if the bones of different fingers have similar responses to sex steroids but differ in their temporal pattern of growth. However, it should be noted that specific direct evidence in terms of the short finger bones is lacking (McIntyre, 2006). Taken together, research has supported 2D4D ratio as a viable biological marker of developmental processes (Manning, Scutt, Wilson & Lewis-Jones,1998) and Voracek, Pietschnig, Nader and Stieger (2011) maintained that associations between 2D4D and psychological variables remain worthy of further consideration.

The 2D4D has been shown to be predictive of sporting performance (Meggs & Golby, 2011). This could be because the nature of sport performance involves male-typical physical and

psychological qualities (e.g., strength, cardiovascular capabilities and psychological toughness) that are beneficial for success.

Previous research using males has highlighted that individuals with low 2D4D typically perform better in sports (Manning & Taylor, 2001), e.g., studies have shown that to be the case in sports such as fencing (Voracek, Reimer & Dressler, 2006), rugby (Bennet, Manning, Cook & Kilduff, 2010), male surfing (Kilduff, Cook & Manning, 2011) and American football (Schorer, Reinhoff, Westphal & Baker 2013). Similar findings have been shown with female samples, e.g., Hull, Schranz, Manning and Tomkinson (2015) found that lower 2D4D ratios were indicative of faster race times in national level rowers. Moreover, Paul, Kato, Hunkin, Vivekanandan, and Spector (2006) also found a negative association between digit ratio and running performance in females. Some meta-analyses have reported similar trends. For example, Honekopp and Schuster (2010) collected data from several studies and included data of 2,810 right hand and 2,791 left 2D4D ratios, finding that athletic performance was negatively linked to 2D4D in both hands. More recent research such as a study by Frick, Hull, Manning & Tomkinson (2017) has found that those competing at higher levels in basketball leagues have lower 2D4D. However 2D4D was not meaningfully related to game-related basketball statistics in national-level players. Another study by Ribeiro et al. (2016) has found that low 2D4D is indicative of better performance in challenging strength task conditions. This suggests that the role of prenatal testosterone in influencing performance is particularly evident when under pressure. However, this interpretation should be treated with caution as studies have reported equivocal findings; i.e., some studies have found negative correlations between 2D4D ratio and masculinity in male samples (Vorecek et al., 2011).

Research has also sought to identify the underpinning psychological variables that may explain this athletic bias. For example, Golby and Meggs (2011) showed that those with lower 2D4D reported higher levels of optimism, task and ego goal orientations and mental toughness. Mental toughness is thought to be a collection of cognitive, affective and behavioural characteristics (a psychological resource) that allow an individual to manage the stressors of competition and perform well (Gucciardi, Gordon & Dimmock, 2008). The characteristics of mental toughness include control (feeling in control of one's emotions during a match), confidence (having belief in one's ability to achieve a successful pass/shot), challenge (perceiving competition to be an opportunity for success and skill improvement) and commitment (being immersed in the sport and attending training or a commitment to values and excellence in sport). It appears that such characteristics would enable an athlete to perform successfully. There is some on-going debate as to whether mental toughness is a trainable construct or a stable and enduring trait. For example, research by Connaughton, Wadey and Jones (2008), Connaughton, Hanton and Jones (2010), Coulter, Mallett and Gucciardi (2010), Gucciardi, Gordon and Dimmock (2009) and Thelwell, Such, Weston, Such, and Greenlees (2010) all suggest that specific aspects of mental toughness can be potentially developed and taught in a sporting environment. Having said this, it still remains an important avenue to identify biological markers of mental toughness so that individual differences can be identified. Biological markers can identify the potential for mental toughness development and consider the effect of socialization upon these biological underpinnings. For example, those with low 2D4D may demonstrate a greater propensity for mental toughness development (Golby & Meggs, 2011) but those with high 2D4D could possibly be targeted for assistance with psychological skills training programs to develop mental toughness.

Previous research has found that males demonstrate higher levels in all mental toughness subscales (Andrews & Chen, 2014; Nicholls, Polman & Levy, 2009) compared to females. However, male and female categorization as a dichotomous split may be limited in that males and females can differ as to how they identify with the male or female stereotypical norms. In keeping with this notion, research has sought to identify if 2D4D is linked with gender identification (i.e., the extent to which men and women identify with masculine or feminine stereotypes). It would logically follow that 2D4D would be negatively associated with sex role orientation. Csatho, Osvath, Bicsak, Karadi, Manning and Kalai (2003) investigated this association with 46 female students and found that those with lower, more male typical digit ratios scored higher on the masculinity subscale but lower on the femininity scale of the Bem Sex Role Inventory (BSRI, Bem 1981). However, the findings of Csatho et al. (2003) were not subsequently replicated in a similar sized sample (Vorecek et al., 2011) and this prediction has yielded inconsistent findings; some small-sample studies have found this predicted effect (e.g., Beech & Mackintosh, 2005) with other large-scale studies (e.g., Lippa, 2006) not finding the expected effect. However, it should be considered that some of these null findings may be due to differences in task specific factors (e.g. sensation seeking; Voracek, Tran & Dressler, 2010, spatial ability; Puts, McDaniel, Jordan & Breedlove). In other research, Rammsayer and Troche (2007) administered the German adapted BSRI to 432 male and 312 female participants and found that males scored higher on the masculinity subscale and females on the femininity subscale. However, no significant relationships were identified between female 2D4D and BSRI scores, whereas it was found that males with low 2D4D self-reported lower scores on the femininity subscale.

There remains a dearth of research of female participants when examining 2D4D and psychological traits, therefore a female sample of athletes were chosen in this study. Moreover, the current study includes a sport-specific sample as mental toughness could be partially context specific (Crust, 2007; Gucciardi, 2017). More specifically, netball players have likely been exposed to playing their sport from a young age in secondary education and therefore provided an opportunity to study women who have been socialized in a sporting context. First, this study will examine the relationships between 2D4D, mental toughness and gender role identity in order to replicate previous findings with this sport specific female sample. Csatho et al (2003) found a negative relationship between digit ratio and masculinity but no sport research has provided support of this finding in a female sporting population. Although, mental toughness has been associated with masculine traits previously (Andrews & Chen, 2014) and studies have found that males are more confident and mentally tough than female athletes (Vealey, 1988; Nicholls et al, 2009), given the findings of Csatho et al (2003) and Beech & Mackintosh (2005) it is predicted that digit ratio will show a negative relationship with characteristics such as commitment, emotional control and life control and that masculinity positively correlate with the MT subscales in a female sport sample. Second, this study aimed to explore the differences between 2D4D, mental toughness and gender role identity. In line with previous research, the second hypothesis predicts that those with low 2D4D would report significantly higher levels of mental toughness, lower levels of femininity and higher levels of masculinity than those with high 2D4D (Golby & Meggs, 2011). Third, the study aimed to explore the differences in mental toughness and gender role identity between netball players of different competitive standards. The third hypothesis anticipated that netballers competing at the higher levels of achievement

will demonstrate lower 2D4D ratio, higher mental toughness levels and masculinity and lower femininity.

Method

Design

The study employed a cross-sectional, descriptive research design. The between subject factors were competition standard with two levels: recreational and regional/national level and digit ratio with high and low levels. The dependent variables were mental toughness and gender role identity.

Participants

The participants were a purposive sample of 116 female netballers from North Yorkshire who were either competing at a local, recreational level (n = 59) or at regional/national standard (n = 57). The mean age of the sample was 22.34 years (SD = 2.23). The majority of the participants were right handed (n = 81).

Measures

MTQ48 mental toughness measure. The 48-item version of the Mental Toughness Questionnaire (MTQ48; Clough, Earl & Sewell, 2002) measures mental toughness in total as well as having six individual subscales. Example items include “Challenges usually bring out the best in me" (challenge); “I can generally be relied upon to complete the tasks I am given” (commitment); “I tend to worry about things well before they actually happen" (emotional control); “I generally feel in control” (life control); “I am generally confident in my own

abilities" (confidence in own abilities); "I am comfortable telling people what to do" (interpersonal confidence). The traits are measured on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire has been found to be a robust psychometric measure of mental toughness (Perry, Clough, Crust, Earle & Nicholls, 2013). The internal consistency of the MTQ48 has been previously investigated with results finding that the overall Cronbach's alpha value is .87 with scores ranging between .58 and .71 (Nicholls, Polman, Levy & Backhouse, 2009). Clough et al. (2002) provided evidence for the construct validity of the MTQ48 with significant relationships reported with optimism (r = .48), self-image (r = .42), life satisfaction (r = .56), self-efficacy (r = .68) and trait anxiety (r = .57). In respect of criterion validity, Clough et al. (2002) found participants with self-reported high, as opposed to low mental toughness gave lower rating of exertion during a 30-minute physically demanding cycling task. The MTQ48 has also been found to correlate with pain tolerance (Crust & Clough, 2005).

BSRI gender role self-report measure. The Bem Sex Role Inventory (BSRI; Bem, 1981) is a self-report which measures how the respondent fits into gender stereotypes of masculinity and femininity. It operates on the basis that masculinity and femininity are both within the psychological androgyny rather than the previous assumption that both traits were at opposed ends of a single dimension. The BSRI (full version) has 60 personality characteristics which are measured on a Likert scale ranging from 1 (never or almost never) to 7 (always or almost always true). Of the 60 personality characteristics 20 assess masculinity (e.g, assertive, willing to take risks), 20 assess femininity (e.g, compassionate, gentle) and 20 are fillers (e.g, moody, jealous) which have no scoring value. The internal consistency of the sub traits has been assessed; the Cronbach's alpha for the masculine subscale is .87, feminine is .77 and .64 for the

fillers (Gaunt, 2006). The internal validity of the measure has been deemed to be adequate (Holt & Ellis, 1998).

Digit ratio measure. A portable flat-bed scanner was connected to a laptop to take scans of the participant's right hands. The 2D4D ratio was created using the digit ratios which were measured using Vernier calipers; accurate to .01mm (Manning, et. al., 1998).

Procedure

Prior to data collection ethical approval was granted by Sheffield Hallam University ethics committee. Next, six local netball clubs (i.e purposive sample) were contacted to explain the aims and expectations of the study and obtain consent. Following this, individual participant consent was obtained and a competition tournament was attended where participants were invited to provide digital hand scans of their right hands (using standardised instructions of; "please remove any jewelry and to place their hand gently onto the flatbed scanner" and complete the MTQ48 and BSRI measures (in that order) in a private room on site. Participants were thanked for their involvement in the study and provided with a full debrief on completion.

Data analysis

Using calculations based on the normal distribution and Cohen's d effect size guidelines (Rosner, 2010) retrospective power-analysis (Thomas, 1997; Gerard, Smith & Weerakkody, 1998; Hogarty & Kromrey, 2003) with a small, medium and large effect sizes of .2, .5 and .8 respectively was conducted (Cohen, 1988), $\alpha = .05$ and $N_1 = N_2 = 58$. Descriptive statistics for the whole sample and the two factors of competition standard (competitive and recreational) and digit ratio (high and low) for each subscale were calculated.

Regarding the first hypothesis, a Pearson's correlation was done to investigate the association between gender role (femininity and masculinity) and mental toughness. For the second and third hypotheses, data was checked for univariate parametric assumptions prior to the inferential analysis including normal distribution (Kolomonogrov-Smirnov statistic; $p > .05$).

The additional assumptions for MANOVA including multivariate outliers, absence of multicollinearity and equality of covariance were also checked. The inter-rater reliability (the relationship between the measurements taken by two independent researchers) of the right hand 2D4D ratio was high ($r = .98$). Digit ratio was categorized into high (> .98) and low (< .98) groups utilizing a median-split as such an approach was used by Golby & Meggs (2011).

For the second and third hypothesis, a two-way between subjects MANOVA was conducted to explore the differences in mental toughness and masculinity and femininity between competition standard (recreational and competitive) and digit ratio (high and low). The multivariate and univariate significance values and effect sizes are reported. The partial eta squared effect sizes are interpreted using the following guidelines; .01-.059 (small), .06-.129 (medium) and .13 + (Large) (Cohen, 1988). With two predictor variables, the effect size descriptors of eta squared can be applied to partial eta squared (Levine & Hullet, 2002). IBM SPSS (Version 24) was used for all statistics.

Results

The retrospective power analysis using small, medium and large effect sizes revealed statistical power estimates of .19, .77 and .99 respectively. Therefore, only medium and large effect sizes will be interpreted in the current study.

Descriptive statistics for the overall sample (Table 1) showed similar variation within each of the Mental toughness (MT) subscales. Challenge ($M = 23.04$, $SD = 4.56$), Commitment

(*M* = 45.28, *SD* = 4.25), Emotional control (*M* = 22.75, *SD* = 4.53), Life control (*M* = 22.67, *SD* = 4.50), Confidence in ability (*M* = 45.10, *SD* = 4.21), Interpersonal confidence (*M* = 21.47, *SD* = 4.43). Pearson's correlation analysis (Table 1) revealed relationships between the mental toughness subscales with masculinity, femininity and 2D4D ratio ranging between *r* = (-.78 - .78). There were significant moderate negative correlations of digit ratio with emotional control, *r* = -.65, *p* <.01, life control, *r* = -.70, *p* <.01 and interpersonal confidence, *r* = -.78, *p* <.01. There was one significant, low, positive correlation between masculinity and the MT subscale of interpersonal confidence, *r* = .37, *p* < .05, only. Masculinity and femininity showed a low positive correlation, *r* = .26, *p* <.01. There were no significant correlations between femininity with any MT subscale.

Prior to MANOVA, the assumptions check found no multivariate outliers and absence of multicollinearity and equality of covariance were also satisfied. The MANOVA interaction effect was not significant; $F(8,105) = 1.45$, $p > .05$, Wilks $\Lambda = .90$, partial $\eta = .10$, power = .63. A large multivariate main effect for right hand digit ratio was shown, $F(8,105) = 7.57$, $p < .001$; Wilks $\Lambda = 0.63$, partial $\eta = .37$, power = 1.0. There were significant differences in all variables between those who have low and high digit ratio ratings (see Table 2). The large effect sizes between low and high digit ratio's were in emotional control (*M* = 25.09, *SD* = 3.43 versus *M* = 20.33, *SD* = 4.27) , life control (*M* = 25.15, *SD* = 3.42 versus *M* = 20.10, *SD* = 4.03), interpersonal confidence (*M* = 23.78, *SD* = 2.89 versus *M* = 18.42, *SD* = 4.10), and masculinity (*M* = 108.90, *SD* = 10.08 versus *M* = 97.70, *SD* = 16.81), where low digit ratio was significantly higher than high digit ratio for all variables. There was also a large multivariate main effect for competition level, $F(8,105) = 3.09$, $p < .005$, Wilks $\Lambda = .81$, partial $\eta = .19$, power = .95. Only challenge showed a medium effect size with those competing at competitive (*M* = 22.23, *SD* =

4.50) level significantly lower than recreational level (*M* = 23.83, *SD* = 4.51) athletes. There was a small effect size in masculinity with competitive (*M* = 102.86, *SD* = 14.09) athletes significantly lower than recreational (*M* = 103.95, *SD* = 15.71) athletes. No other variables were significantly different between competition levels (See Tables 1 & 2 for the descriptive statistics and Table 3 for inferential statistics).

Discussion

Previous research has identified and supported a negative relationship between finger digits (growth of the 4th finger) and levels of prenatal testosterone (Manning, 2002) and that individuals low in 2D4D perform better at sports (Voracek, Reimer & Dressler, 2006). Although, this suggests a role of both mental toughness and prenatal testosterone in influencing performance under pressure, there is a lack of research exploring how identification with male or female norms influences these variables. Therefore, the first aim of the study was to examine relationships between 2D4D, mental toughness and gender role identity in females. The prediction was that digit ratio will show negative relationships with the MT subscales of commitment, emotional control and life control and while masculinity will show positive relationships with the MT subscales. This hypothesis was not fully supported. Digit ratio showed moderate negative correlations with emotional control, life control and interpersonal confidence. This indirectly supports the idea of prenatal testosterone being associated with important mental toughness characteristics in a female sports sample. Masculinity and femininity also showed a significant but low positive correlation. However, the only significant positive relationship between gender role identity with MT, was between masculinity and interpersonal confidence. Nevertheless, these mental toughness characteristics and gender profile, have important implications for allowing female individuals to manage stressful sporting environments. A high

scoring masculinity and femininity gender profile is typically termed ‘androgynous’ (HiroKawa, Yamada & Dohi, 2001). This profile could indicate identification with traits associated with emotional intelligence, such that an individual is able to identify their own and others emotions and manage them effectively in a team sport environment (Rutkowska & Bergier (2013). For example, Hirokawa et al., (2001) in a laboratory study, found that both females and males experienced a reduction in stress levels when in conversation with an androgynous partner compared to a sex-typed partner. This reduction in stress is thought to be a function of the interpersonal skills of the androgynous individual. Other researchers have argued that androgynous individuals could be better equipped in terms of interpersonal adjustment than other groups (Johnson & Brems, 1989; Petry & Thomas, 1986). Rutkowska & Bergier (2013) found that androgynous female soccer players scored significantly higher in emotional intelligence compared to a sex typed female sample. Such identification with traits such as competitiveness and assertiveness are likely to prove an advantage in a sporting context. The presence of such stereotypically male characteristics, and there potential biological basis, helps reinforces the notion of these variables existing on a continuum in the female population.

The second aim of this study was to identify the differences between high and low 2D4D,in both mental toughness and gender role identity. The second hypothesis predicted that those with low 2D4D would report significantly higher levels of mental toughness, lower levels of femininity and higher levels of masculinity than those with high 2D4D. As expected, a low 2D4D right hand digit ratio was typical of those with higher levels of emotional control, life control, interpersonal confidence and masculinity which all had large effects. Its interesting that two of the four large effects – life control and interpersonal confidence - can be interpreted as social-psychological variables (the relational aspects of mental toughness). It may be that a lower

digit ratio is associated with characteristics that enable females to successfully manage their interpersonal relationships to optimize the pursuit of their goals (Gucciardi, Gordon & Dimmock, 2008). These results are consistent with previous findings using a female sample that have also found a negative relationship between 2D4D ratios and mental toughness (Golby & Meggs, 2011). The findings support those of previous research that had identified the organisational effect of prenatal testosterone upon the sporting brain (Golby & Meggs, 2011; Reed & Meggs, 2017). Specifically, those with low 2D4D have been shown to have higher levels of determination (conceptually similar to commitment), self-belief (confidence) and positive cognition (Golby & Meggs, 2011). Retrospective power analysis using medium and large effect sizes found acceptable power estimates of 0.77 and 0.99 respectively, therefore, placing more confidence in these interpretations.

The second hypothesis findings underlines the need to identify the links between 2D4D and gender identification in future research. The concept of gender self-identification is important when considering psychological attributes relevant for sport performance. Previous research has often associated successful sporting outcomes with masculine traits, for example, problem focused rather than emotion focused coping (Andrews & Chen, 2014) and lower mental toughness in females compared to males (Nicholls et al, 2009). However, mental toughness and problem focused coping, if accepted as more masculine characteristics, have frequently shown to be positively associated with performance success in a variety of populations (Gucciardi et al, 2009; Mahoney, Gucciardi, Ntoumanis & Mallet, 2014), therefore, the finding of higher masculinity scores for lower digit ratio, suggests that within females, there is important variability in the extent to which individual members identify with masculine traits and this may encourage these individuals to expose themselves to situations that develop mental toughness

(sporting situations) more often than females with higher digit ratios. Indeed, the difference in masculinity between high and low digit ratio had a large effect size, compared to no effect for femininity in the predicted direction. These findings contrast with previous studies for various reasons. For example, Voracek, Pietchnig, Nader & Stieger (2011) found that men's left-hand 2D4D related positively to masculinity scores, which is counterintuitive. However, such findings cannot necessarily be generalized to the females in this sample. Rammsayer and Troche (2007) did not find differences between female 2D4D and BSRI scores in a large student sample. This difference is not surprising however, as previous research on 2D4D and gender identification has shown inconsistent results, which may be due to between population differences across studies. In particular, as the current study used a sporting sample it would be expected that individuals with lower digit ratios would show higher mental toughness, compared to a non-sporting sample.

The third hypothesis was that netballers at the competitive level would demonstrate lower 2D4D ratios, higher mental toughness and masculinity and lower femininity compared to recreational players. This hypothesis was not fully supported, although masculinity was only a small effect and only the challenge variable showed a medium effect size. Counter intuitively, those netballers who were currently playing in competitive regional or national leagues self-reported slightly lower levels of challenge over those who were competing at a recreational level. The precise reasons for this can only be speculated, it could be that specialization of the higher level netballers may weaken intrinsic motivation which could manifest in variable challenge perceptions of competition (Russell, Dodd & Lee, 2017). Although, previous research has found females to have lower global mental toughness compared to males, it could be that even at high competitive levels, female athletes may exhibit less consistent perceptions regarding specific aspects of mental toughness across time due to wider variations in masculine traits within the

population. Although, research elsewhere has found that high levels of masculinity are related to high levels of mental toughness (in both boys and girls) and the importance of socialisation and gender roles have been highlighted (Strycharcyk & Clough, 2014) the relative impact of these factors within females is unknown. Tentatively, this finding suggests that prenatal factors (such as hormonal exposure) could present a potential for identification with masculine traits, of which one is the interpersonal aspects of mental toughness. In netball, women are exposed to stereotypically male behaviours, such as competition and aggression although it is unknown to what extent those experiences are an outcome or a consequence of higher levels of mental toughness. Further experimental research is needed to breakdown the antecedents of mental toughness differences at different levels of competition and the relationship with gender role identity within females. With further research a better understanding of the biological contribution to sporting success and key psychological variables can be established along with the nature of socialization. If mental toughness is developed by involvement in the sporting environment (exposure to 'masculine' traits such as competitiveness and independence) then competitive sport could be an arena wherein resilience to stress can be cultivated.

There are some limitations to this study. Firstly, there was no current performance measure assessed and therefore the relationship between 2D4D and on-going performance level is unknown. This limits the comparison of the present findings to the studies of Hull, et al. (2015) and Paul et al., (2006) who did assess current performance. Secondly, although mental toughness differences were found within digit ratios some of the subscale effects were small and it is unknown to what extent these variables would help deal with competitive stressors. Perhaps future research may wish to assess the interaction between prenatal hormone exposure, childhood experiences (in terms of socialisation with gender stereotypes) and mental toughness

levels. It appears logical that those who identify with masculine traits may also self-report high levels of mental toughness; as the characteristics of mental toughness (i.e., independent, stubborn mindedness, and determination to succeed) are typically associated with a masculine stereotype (Strycharcyk & Clough, 2014). Whether this identification is a result of prenatal hormone exposure or socialisation, or an interaction between the two, is yet to be fully explored. The nature of a sport is an integral part of an athlete's socialisation and therefore male dominated sports such as football and rugby may lead to different gender identifications in women.

In summary, the results from this study although promising, do not give full support for differences in digit ratio on mental toughness and gender role identity or that competitive females have higher MT, masculinity and lower femininity. The influence of digit ratio indicates a link with a potential biomarker but more research is needed to further describe these relationships with a wide variety of sporting populations and research designs that track changes over time. Future research may wish to explore the association between gender role identification, 2D4D and mental toughness in male dominated sports. Moreover, the cross-sectional nature means that the stability of these relationships cannot be explored; prospective studies would allow mental toughness and gender role identification to be predicted from 2D4D ratios. It may also be worth exploring if females with higher digit ratios have similar coping strategies when dealing with competitive stress compared to males. Lastly, the research can only be considered in the social context of netball, perhaps future research may wish to explore the nature of these relationships in various sports. Previous research has highlighted coping differences between the genders. However, this does not take into account the variation in prenatal hormone exposure which may indicate high levels of masculine identification in females with high digit ratios. Finally, the inclusion of a median-split of 2D4D limits the generalizability

of the findings. Future research may wish to develop established group norms for specific sub-groups so that a universal categorization of 2D4D into high and low categories is possible.

References

Andrews, P., & Chen, M.A. (2014) Mental toughness and gender differences in coping with injury in runners. *Journal of Athletic Enhancement*, 3, 6. doi:10.4172/2324-9080.1000183.

Beech, J. R., & Mackintosh, I. C. (2005). Do differences in sex hormones affect handwriting style? Evidence from digit ratio and sex role identity as determinants of the sex of handwriting. *Personality and Individual Differences, 39,* 459–468. Dx.doi.org/10.1016/j.paid.2005.01.024.

Bem, S. L. (1981*). Bern Sex-Role Inventory: Professional manual*. Palo Alto, CA: Consulting Psychologists Press.

Bennett, M., Manning, J. T., Cook, C. J., & Kilduff, L. P. (2010). Digit ratio (2D: 4D) and performance in elite rugby players. *Journal of sports sciences*, *28*(13), 1415- 1421. 10.1080/02640414.2010.510143.

Clough, P. J., Earle, K., & Sewell, D. (2002). Mental toughness: the concept and its measurement. In I. Cockerill (Ed.). *Solutions in Sport* Psychology (pp. 32-43). London: Thomson.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd edition). Routledge, London.

Connaughton, D., Wadey, R., Hanton, S. & Jones, G. (2008). The development and maintenance of mental toughness: perceptions of elite performers. *Journal of Sports Science* **26**, 83-95. DOI: 10.1080/02640410701310958

Connaughton, D., Hanton, S., & Jones, G. (2010). The development and maintenance of mental toughness in the world's best performers. *The Sport Psychologist 24* (2), 168-193. **doi**.org/10.1123 /tsp.24.2.168

Coulter, T. J., Mallett, C. J., & Gucciardi, D. F. (2010). Understanding mental toughness in Australian soccer: Perceptions of players, parents, and coaches. *Journal of Sports Sciences* **11** (28) 699-716. DOI:10.1080/02640411003734085

- Crust, L. (2007). Mental toughness in sport: A review. *International Journal of Sport & Exercise Psychology* **5** (3), 270-290. doi.org/10.1080/1612197X.2007.9671836

Csatho, A., Osvath, A., Bicsak, E., Karadi, K., Manning, J., & Kalai, J. (2003). Sex role identity related to the ratio of second to fourth digit ratio in women. *Biological Psychiatry* **62**, 147- 156. DOI: 10.1016/S0301-0511(02)00127-8

Frink, N.A, Hull, M.J, Manning, J.T. & Tomkinson, G.R. (2017). Relationships between digit ratio (2D4D) and basketball performance in Australian men. *American Journal of Human Biology*, 1-6. DOI: 10.1002/ajhb.22937

Gerard, P.D., Smith, D.R., & Weerakkody, G.(1998) Limits of retrospective power analysis. *Journal of Wildlife Management*, 62, 801-807.

Golby, J., & Meggs, J. (2011). Exploring the organisational effect of prenatal testosterone upon the sporting brain. *The journal of Sport Science and Medicine* **10**, 445-451.

- Gucciardi, D., Gordon, S., & Dimmock, J. (2008). Towards and understanding of mental toughness in Australian football. *Journal of Applied Sport Psychology* **20**, 261-281. doi.org/10.1080/10413200801998556

- Gucciardi, D., Gordon, S., & Dimmock, J. (2009). Advancing mental toughness research and theory using personal construct psychology. *International. Review of Sport and Exercise. Psychology* **2** 54–72. doi.org/10.1080/17509840802705938

HiroKawa, K., Yamada, F., & Dohi, I (2001). Effect of gender-types on interpersonal stress measured by blink rate and questionnaires: Focusing on stereotypically sex-typed and androgynous types, *Social Behavior and Personality*, 29, 4, 375-384. DOI: https://doi.org/10.2224/sbp.2001.29.4.375

Hogarty, K & Kromrey, J.D. (2003) RETR_PWR: An SAS macro for retrospective statistical power analysis. *Behaviour Research Methods, Instruments and Computers*. 35, 4, 585-589.

Holt, C. L. & Ellis, J. B. (1998). Assessing the current validity of the BEM sex-role inventory. *Sex roles*, 39, 929-941. http://dx.doi.org/10.1023/A:1018836923919

Honekopp, J., Manning, J.T., & Muller, C. (2006). Digit ratio (2D4D) and physical fitness in males and females: Evidence for effects of prenatal androgens on sexually selected traits, *Hormones and Behavior* **49**, 545-549. DOI:10.1016/j.yhbeh.2005.11.006

Honekopp J, Schuster M. A meta-analysis on 2D4D and athletic prowess: substantial relationships but neither hand out-predicts the other. *Personality and Individual Differences*. 2010;48:4–10. http://dx.doi.org/10.1016/j.paid.2009.08. 009

Hull, M., J., Schranz, N., K., Manning, J., T., & Tomkinson, G. R. (2015). Relationships between digit ratio (2D4D) and female competitive rowing performance. *American journal of Human Biology* **27** (2), 157-163. DOI:10.1002/ajhb.22627

Johnson, M. E., & Brems, C. (1989). Differences in interpersonal functioning as related to sex-role orientation. *Psychology-Journal of Human Behavior*, 26, 48-52.

Kilduff, L.P., Cook, C.J., Manning, J.T. (2011). Digit ratio (2D4D) and performance in male surfers. *Journal of Strength and Conditioning Research* 25:3175-3180. DOI: 10.1519/JSC. 0b013e318212de8e.

Levine, T.R & Hullet, C.R. (2002) Eta squared, partial eta squared and misreporting of effect size in communication research. *Human Communication Research*, 28, 4, 612-625. https://doi.org/10.1111/j.1468-2958.2002.tb00828.x

Lippa, R. A. (2006). Finger lengths, 2D4D ratios, and their relation to gender related personality traits and the Big Five. *Biological Psychology*, 71, 116–121. DOI:

10.1016/j.biopsycho.2005.02.004

Mahoney, J.W., Gucciardi, D.F., Ntoumanis, N., & Mallet, C.J. (2014) Mental toughness in sport: Motivational antecedents and associations with performance and psychological health. *Journal of Sport and Exercise Psychology*, 36, 281-292.

Malas, M.A., Dogan, S., Evcil, E.H., & Desdicioglu, K. (2006). Fetal development of the hand, digits and digit ratio (2D: 4D). *Early Human Development* **82**, 469–475.

Manning, J.T., (2002). Digit Ratio: A Pointer to Fertility, *Behaviour, and Health*. Rutgers Univ. Press, New.

Manning, J. T., Scutt, D., Wilson, J., & Lewis-Jones, D., I. (1998). The ratio of 2nd to 4th digit length: A predictor of sperm numbers and levels of testosterone, luteinizing hormone and oestrogen. *Human Reproduction* **13** (11), 3000-3004.

Manning, J., T., & Taylor, R., P. (2001). Second to fourth digit ratio and male ability in sport: implications for sexual selection in humans. *Evolution and Human behavior* **22,** (1), 61-69.

Meggs, J. & Golby, J. (2011). Exploring the organizational effect of prenatal testosterone upon the sporting brain. *Journal of Sport Science and Medicine*, 10, 445-451.

McIntyre, M., H., Ellison, P., T., Lieberman, D., E., Demerath, E., Towne, B. (2005). The development of sex differences in digital formula from infancy in the Fels Longitudinal Study. Proceedings of the Royal Society B: *Biological Sciences* 272, 1571-1473. doi: 10.1098/rspb.2005.3100

McIntyre, M., H. (2006) The use of digit ratios as markers for perinatal androgen action. *Reproductive Biology and Endocrinology*, 4, 10, doi.org/10.1186/1477-7827-4-10.

Nicholls, A. R., Polman, R. C., Levy, A. & Backhouse, S. (2009). Mental toughness in sport: Achievement level, gender, age, experience and sport type. *Personality & Individual Differences* **47**, 73- 75. https://doi.org/10.1016/j.paid.2009.02.006

Paul, S. N., Kato, B.S., Hunkin, J.L., Vivekanandan, S., Spector, T.D. (2006). The big finger: the second to fourth digit ratio is a predictor of sporting ability in women. *British Journal of Sports Medicine* 40:981–3. DOI: 10.1136/ bjsm.2006.027193

Perry, J. L., Clough, P. J., Crust, L., Earle, K. & Nicholls, A. R. (2013). Factorial validity of the mental toughness questionnaire-48. *Personality and Individual Differences* **54**, 5, 587-5926.

Petry, R. A., & Thomas, J. R. (1986). The effect of androgyny on the quality of psycho-therapeutic relationships. *Psychotherapy*, 23, 249-251. http://dx.doi.org/10.1037/h0085605

Puts, D. A., McDaniel, M. A., Jordan, C. L., & Breedlove, S. M. (2008). Spatial ability and prenatal androgens: Meta-analyses of congenital adrenal hyperplasia and digit ratio (2D4D) studies. *Archives of Sexual Behavior*, 37, 100–111. DOI 10.1007/s10508-007 9271-3

Rammsayer, T., & Troche, S. J. (2007). Sexual dimorphism in the second-to-fourth digit ratio and its relation to gender-role role in males and females. *Personality and Individual Differences* **42**:911–920. DOI: 10.1002/ajhb.21054

Reed, S., & Meggs, (2017). Examining the effect of prenatal testosterone and aggression on sporting choice and longevity. *The Journal of Personality and Individual Differences*. DOI: 10.1016/j.paid.2017.04.022.

Ribeiro Jr, E. Neave, N., Morais, R.N., Kilduff, L., Taylor, S.R., Butovskaya, M., Fink, B. & Manning, J.T. (2016) Digit ratio (2D4D), testosterone, cortisol, aggression, personality and hand-grip strength: Evidence for prenatal effects on strength. *Early Human Development*, 100, 21-25.

Rosner, B. (2010) Fundamentals of Biostatistics (7th edition). Blackwell. London.

Russell, W., Dodd, R., & Lee, M. (2017) Youth athletes' sport motivation and physical activity enjoyment across specialization status. *Journal of Contemporary Athletics*, 11, 2, 83-95.

Rutkowska, K & Bergier, J. (2013) Psychological Gender and Emotional Intelligence in Youth Female Soccer Players , *Journal of Human Kinetics*, 47/2015, 285-291 DOI: 10.1515/hukin-2015-0084

Schorer, J., Reinhoff, R., Westphal, H., & Baker, J. (2013) Digit ratio effects between expertise levels in American football players. *Talent Development and Excellence*, 5, 2, 113-116.

Strycharcyk, D., & Clough, P. (2014). *Developing mental toughness in young people: Approaches to achievement, well-being and positive behavior*. Karnac Books.

Thelwell, R. C., Such, B. A., Weston, N. J. V., Such, J. D., & Greenlees, I. A. (2010). Developing mental toughness: Perceptions of elite female gymnasts. *International Journal of Sport and Exercise Psychology* **8**(2), 170-188. https://doi.org/10.1080/1612197X.2010.9671941

Thomas, R. (1997) Retrospective power analysis. *Conservation Biology*, 11, 1, 276-280.

Trivers, R., Manning, J., T. & Jacobson, A. (2006). A longitudinal study of digit ratio (2D4D) and other finger ratios in Jamaican children. *Hormones and Behaviour* **49** (2), 150- 156. http://dx.doi.org/10.1016/j. yhbeh.2005.05.023.

Vealey, R.S. (1988) Sport confidence and competitive orientation: An addendum on scoring procedures and gender differences. *Journal of Sport and Exercise Psychology*, 10, 471-478.

Voracek, M., Tran, U. S., & Dressler, S. G. (2010). Digit ratio (2D4D) and sensation seeking: New data and meta-analysis. *Personality and Individual Differences*, 48,72–77. http://dx.doi.org/10.1016/j.paid.2009.08.019.

Voracek, M., Pietschnig, J., Nader, I. W., & Stieger, S. (2011). Digit ratio (2D4D) and sex-role orientation: Further evidence and meta-analysis. *Personality and Individual Differences, 51*(4), 417-422. http://dx.doi.org/10.1016/j.paid.2010.06.009.

Voracek, M., Reimer, B., Ertl, C., & Dressler, S.G. (2006). Digit ratio (2D4D), lateral preferences, and performance in fencing. *Perceptual and Motor Skills* **103**, 427-446. http://dx.**doi**.org/10.2466/PR0.100.1.115-126

584 **Table 1.** Pearsons correlation matrix for measured relationships between variables and

585 descriptive statistics for the whole sample

586

	1	2	3	4	5	6	7	8	9
1. Challenge		.20* (.09,.37)	.10 (-.08,.28)	.12* (-.07,.29)	.19* (.00, .36)	.14 (-.04,.31)	.11 (-.08,.28)	-.03 (-.21,.15)	-.15 (-.32,.04)
2.Commitment			.15* (-.04,.32)	.16* (-.02,.33)	.95** (.92,.97)	.17 (-.02,.39)	.18 (.07,.41)	.13 (-.05,.31)	-.30** (-.46,-.12)
3. Emotional control				.78 (.70,.84)	.10 (-.08,.28)	.88 (.83,.96)	.26 (-.08,.42)	.13 (-.03,.37)	-.65** (-.74,-.53)
4.Life control					.10* (-.08,.28)	.92* (.89,.94)	.34 (.17,.49)	.10 (-.08,.27)	-.70** (-.78,-.60)
5. Confidence in ability						.11 (-.07,.29)	.15 (-.03,.32)	.11 (-0.07,.29)	-.27** (-.45,-.12)
6. Interpersonal confidence							.37** (.20,.52)	.14 (-.04,.31)	-.78* (-.84,-.69)

7. Masculinity								.26** (.09,.42)	-.15 (-.32,.04)
8. Femininity									.01 (-.17,.19)
9. 2D4D									
Mean (SD)	23.04 (4.56)	45.28 (4.25)	22.75 (4.53)	22.67 (4.50)	45.10 (4.21)	21.47 (4.43)	103.40 (14.85)	92.22 (15.63)	0.95 (0.03)
Min/Max	12/32	38/52	13/30	14/32	38/52	12/29	67/121	1/124	.90/1.01

Table 2. Mean (*SD*) MTQ48 subscales and BSRI masculinity and femininity main effects of digit ratio and competition level.

	Main effect		Main effect	
Variable	Low digit ratio	High digit ratio	Recreational	Competitive
MTQ48				
Challenge	23.41 (4.44)	22.67 (4.68)	23.83 (4.51)	22.23 (4.50)
Commitment	46.63 (4.45)	43.88 (3.56)	44.04 (3.87)	46.56 (4.27)
Emotional control	25.09 (3.43)	20.33 (4.27)	21.39 (4.29)	24.16 (4.37)
Life control	25.15 (3.42)	20.10 (4.03)	21.08 (4.45)	24.32 (3.96)
Confidence in abilities	46.29 (4.48)	43.88 (3.56)	44.03 (3.87)	46.21 (4.30)
Interpersonal confidence	23.78 (2.89)	18.42 (4.10)	19.58 (4.47)	22.77 (3.78)
BSRI				
Masculinity	108.90 (10.08)	97.70 (16.81)	102.86 (14.09)	103.95 (15.71)
Femininity	94.71 (12.78)	89.65 (17.88)	92.29 (12.63)	92.22 (15.64)

Table 3. MANOVA and Univariate ANOVA results for the right hand digit ratio and competition level main effects

Main effect/Variable	Wilks Λ	DoF / *F* ratio	*p* value	Partial η^2	Descriptor
Right hand digit ratio	.634	$F(8,105) = 7.57$	$p < .001$	.37	Large
Challenge		$F(1,112) = 4.34$	$p < .05$	.04	Small
Commitment		$F(1,112) = 5.86$	$p < .05$	.05	Small
Emotional control		$F(1,112) = 29.28$	$p < .001$	.21	Large
Life control		$F(1,112) = 32.9$	$p < .001$	.23	Large
Confidence in abilities		$F(1,112) = 4.49$	$p < .05$	.04	Small
Interpersonal confidence		$F(1,112) = 43.62$	$p < .001$	.28	Large
Masculinity		$F(1,112) = 24.40$	$p < .001$	.18	Large
Femininity		$F(1,112) = 5.01$	$p < .05$	.04	Small
Competition level	.81	$F(8,105) = 3.09$	$p < .005$	.19	Large
Challenge		$F(1,112) = 7.28$	$p < .05$	.06	Medium
Commitment		$F(1,112) = 3.19$	$p > .05$	.03	Small
Emotional control		$F(1,112) = 0.53$	$p > .05$	.01	Small
Life control		$F(1,112) = 1.67$	$p > .05$	.01	Small
Confidence in abilities		$F(1,112) = 2.23$	$p > .05$	.02	Small
Interpersonal confidence		$F(1,112) = 1.10$	$p > .05$	.01	Small
Masculinity		$F(1,112) = 4.22$	$p < .05$	0.036	Small
Femininity		$F(1,112) = 1.431$	$p > .05$	0.031	Small

614